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IEEE STD IEEE Standard

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Apr 12, 2005

US-PAT-NO: 6880149

DOCUMENT-IDENTIFIER: US 6880149 B2

TITLE: Method for runtime code integrity validation using code block checksums

DATE-ISSUED: April 12, 2005

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Cronce; Paul A.	San Jose	CA		

US-CL-CURRENT: [717/126](#); [713/165](#), [713/166](#), [714/38](#), [714/48](#), [717/124](#), [717/139](#)

ABSTRACT:

The present invention provides a method and system for runtime code integrity validation. The method and system include providing a software tool for processing a software program, as well as instructions on how to modify the software program for submission to the tool. The modified software program executable generated for submission to the tool includes checksum information for use by the tool. The tool uses the checksum information to compute checksums on blocks specified by the checksum information, and stores the computed checksums in locations specified by the checksum information. Next, the tool strips the checksum information from the executable. The resulting executable code is delivered as a protected software application that generates a new checksum at runtime and compares it with the computed checksum, and determines that the software program has been modified if the checksums fail to match.

36 Claims, 11 Drawing figures

Exemplary Claim Number: 1

Number of Drawing Sheets: 10

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## 21 [Achieving extensibility through product-lines and domain-specific languages: a case study](#)



Don Batory, Clay Johnson, Bob MacDonald, Dale von Heeder

 April 2002 **ACM Transactions on Software Engineering and Methodology (TOSEM)**, Volume 11 Issue 2

Publisher: ACM Press

 Full text available: [pdf\(324.37 KB\)](#)

 Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#), [review](#)

This is a case study in the use of *product-line architectures (PLAs)* and *domain-specific languages (DSLs)* to design an extensible command-and-control simulator for Army fire support. The reusable components of our PLA are layers or "aspects" whose addition or removal simultaneously impacts the source code of multiple objects in multiple, distributed programs. The complexity of our component specifications is substantially reduced by using a DSL for defining and refining state machi ...

**Keywords:** GenVoca, aspects, domain-specific languages, refinements, simulation

## 22 [Practical extraction techniques for Java](#)



Frank Tip, Peter F. Sweeney, Chris Laffra, Aldo Eisma, David Streeter

 November 2002 **ACM Transactions on Programming Languages and Systems (TOPLAS)**, Volume 24 Issue 6

Publisher: ACM Press

 Full text available: [pdf\(1.01 MB\)](#)

 Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#), [review](#)

Reducing application size is important for software that is distributed via the internet, in order to keep download times manageable, and in the domain of embedded systems, where applications are often stored in (Read-Only or Flash) memory. This paper explores extraction techniques such as the removal of unreachable methods and redundant fields, inlining of method calls, and transformation of the class hierarchy for reducing application size. We implemented a number of extraction techniques in < ...

**Keywords:** Application extraction, call graph construction, class hierarchy transformation, packaging, whole-program analysis


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## 23 [From Cluster to Wall with VTK](#)

Kenneth Moreland, David Thompson

 October 2003 **Proceedings of the 2003 IEEE Symposium on Parallel and Large-Data Visualization and Graphics PVG '03**

**Publisher:** IEEE Computer Society

Full text available:  [pdf\(279.69 KB\)](#) Additional Information: [full citation](#), [abstract](#)

This paper describes a new set of parallel rendering components for VTK, the Visualization Toolkit. The parallel rendering units allow for the rendering of vast quantities of geometry with a focus on cluster computers. Furthermore, the geometry may be displayed on tiled displays at full or reduced resolution. We demonstrate an interactive VTK application processing an isosurface consisting of nearly half a billion triangles and displaying on a power wall with a total resolution of 63 million pix ...

**Keywords:** parallel rendering, desktop delivery, tile display, PC cluster, Chromium, VTK

24 Pyro: A python-based versatile programming environment for teaching robotics



Douglas Blank, Deepak Kumar, Lisa Meeden, Holly Yanco

December 2003 **Journal on Educational Resources in Computing (JERIC) , Journal on Educational Resources in Computing (JERIC)**, Volume 3 , 4 Issue 4 , 3

**Publisher:** ACM Press

Full text available:  [pdf\(259.97 KB\)](#) Additional Information: [full citation](#), [abstract](#), [references](#), [index terms](#)

In this article we describe a programming framework called Pyro, which provides a set of abstractions that allows students to write platform-independent robot programs. This project is unique because of its focus on the pedagogical implications of teaching mobile robotics via a top-down approach. We describe the background of the project, its novel abstractions, its library of objects, and the many learning modules that have been created from which curricula for different types of courses can be ...

**Keywords:** Mobile robotics, autonomous control, computer science education, education, platform-independent robotics control, programming languages, robot abstractions, top-down instruction

25 Software support: Sympathy for the sensor network debugger



Nithya Ramanathan, Kevin Chang, Rahul Kapur, Lewis Girod, Eddie Kohler, Deborah Estrin

November 2005 **Proceedings of the 3rd international conference on Embedded networked sensor systems SenSys '05**

**Publisher:** ACM Press

Full text available:  [pdf\(252.16 KB\)](#) Additional Information: [full citation](#), [abstract](#), [references](#), [index terms](#)

Being embedded in the physical world, sensor networks present a wide range of bugs and misbehavior qualitatively different from those in most distributed systems. Unfortunately, due to resource constraints, programmers must investigate these bugs with only limited visibility into the application. This paper presents the design and evaluation of Sympathy, a tool for detecting and debugging failures in sensor networks. Sympathy has selected metrics that enable efficient failure detection, and incl ...

**Keywords:** debugging, failure detection, failure localization, root causes, sensor networks

26 Implementation: TypEr: a type annotator of Erlang code

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Tobias Lindahl, Konstantinos Sagonas

September 2005 **Proceedings of the 2005 ACM SIGPLAN workshop on Erlang ERLANG '05**

**Publisher:** ACM Press

Full text available:  [pdf\(282.21 KB\)](#) Additional Information: [full citation](#), [abstract](#), [references](#), [index terms](#)

We describe and document the techniques used in TOOL, a fully automatic type annotator for Erlang programs based on constraint-based type inference of *success typings* (a notion closely

related to principal typings). The inferred typings are fine-grained and the type system currently includes subtyping and subtype polymorphism but not parametric polymorphism. In particular, we describe and illustrate through examples a type inference algorithm tailored to Erlang's characteristics which is ...

**Keywords:** Erlang, constraint-based type inference, principal typings, subtyping, success typings

## 27 Scalability, fidelity, and containment in the potemkin virtual honeyfarm



Michael Vrible, Justin Ma, Jay Chen, David Moore, Erik Vandekieft, Alex C. Snoeren, Geoffrey M. Voelker, Stefan Savage

October 2005 **ACM SIGOPS Operating Systems Review , Proceedings of the twentieth ACM symposium on Operating systems principles SOSP '05**, Volume 39 Issue 5

**Publisher:** ACM Press

Full text available: [pdf\(506.39 KB\)](#) Additional Information: [full citation](#), [abstract](#), [references](#), [index terms](#)

The rapid evolution of large-scale worms, viruses and bot-nets have made Internet malware a pressing concern. Such infections are at the root of modern scourges including DDoS extortion, on-line identity theft, SPAM, phishing, and piracy. However, the most widely used tools for gathering intelligence on new malware -- network honeypots -- have forced investigators to choose between monitoring activity at a large scale or capturing behavior with high fidelity. In this paper, we describe an approa ...

**Keywords:** copy-on-write, honeyfarm, honeypot, malware, virtual machine monitor

## 28 Connectivity-based garbage collection



Martin Hirzel, Amer Diwan, Matthew Hertz

October 2003 **ACM SIGPLAN Notices , Proceedings of the 18th annual ACM SIGPLAN conference on Object-oriented programing, systems, languages, and applications OOPSLA '03**, Volume 38 Issue 11

**Publisher:** ACM Press

Full text available: [pdf\(521.65 KB\)](#) Additional Information: [full citation](#), [abstract](#), [references](#), [citing](#), [index terms](#)

We introduce a new family of connectivity-based garbage collectors (Cbgc) that are based on potential object-connectivity properties. The key feature of these collectors is that the placement of objects into partitions is determined by performing one of several forms of connectivity analyses on the program. This enables partial garbage collections, as in generational collectors, but without the need for any write barrier. The contributions of this paper are 1) a novel family of garbage c ...

**Keywords:** connectivity based garbage collection

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## 29 Exploiting value-added content in an online course: introducing programming concepts via HTML and JavaScript



Joseph L. Zachary, Peter A. Jensen

January 2003 **ACM SIGCSE Bulletin , Proceedings of the 34th SIGCSE technical symposium on Computer science education SIGCSE '03**, Volume 35 Issue 1

**Publisher:** ACM Press

Full text available: [pdf\(161.62 KB\)](#) Additional Information: [full citation](#), [abstract](#), [references](#), [citing](#), [index terms](#)

Online courses have proliferated across all disciplines in recent years. One commonly-used approach for creating an online course is to build a web site containing as much course information---assignments, solutions, lecture notes, streaming videos, and the like---as possible. The goal of this type of course is to replicate online, to the maximum extent possible,

the classroom experience. Online courses built this way exploit the *communications* capabilities of networked computers. We beli ...

**Keywords:** CS0, HTML, JavaScript, online courses

30 Parallel programming with coordination structures



Steven Lucco, Oliver Sharp

January 1991 **Proceedings of the 18th ACM SIGPLAN-SIGACT symposium on Principles of programming languages**

**Publisher:** ACM Press

Full text available: [pdf\(1.14 MB\)](#)

Additional Information: [full citation](#), [references](#), [citations](#), [index terms](#)

31 Features: Commercializing Open Source Software



Michael J. Karels

July 2003 **Queue**, Volume 1 Issue 5

**Publisher:** ACM Press

Full text available: [pdf\(1.11 MB\)](#) [html\(38.31 KB\)](#)

Additional Information: [full citation](#), [abstract](#), [citations](#), [index terms](#)

Many have tried, a few are succeeding, but challenges abound.

32 An empirical study of the reliability of UNIX utilities



Barton P. Miller, Louis Fredriksen, Bryan So

December 1990 **Communications of the ACM**, Volume 33 Issue 12

**Publisher:** ACM Press

Full text available: [pdf\(2.38 MB\)](#)

Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#), [review](#)

The following section describes the tools we built to test the utilities. These tools include the fuzz (random character) generator, *ptyjig* (to test interactive utilities), and scripts to automate the testing process. Next, we will describe the tests we performed, giving the types of input we presented to the utilities. Results from the tests will follow along with an analysis of the results, including identification and classification of the program bugs that caused the crashes. The final ...

33 Fast and flexible application-level networking on exokernel systems



Gregory R. Ganger, Dawson R. Engler, M. Frans Kaashoek, Hector M. Briceño, Russell Hunt, Thomas Pinckney

February 2002 **ACM Transactions on Computer Systems (TOCS)**, Volume 20 Issue 1

**Publisher:** ACM Press

Full text available: [pdf\(500.67 KB\)](#)

Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#)

Application-level networking is a promising software organization for improving performance and functionality for important network services. The Xok/ExOS exokernel system includes application-level support for standard network services, while at the same time allowing application writers to specialize networking services. This paper describes how Xok/ExOS's kernel mechanisms and library operating system organization achieve this flexibility, and retrospectively shares our experiences an ...

**Keywords:** Extensible systems, OS structure, fast servers, network services

34

SIVIL: a true visual programming language for students

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Timothy F. Materson, R. Mark Meyer

April 2001 **Journal of Computing Sciences in Colleges , Proceedings of the sixth annual CCSC northeastern conference on The journal of computing in small colleges,**  
Volume 16 Issue 4

**Publisher:** Consortium for Computing Sciences in Colleges , Consortium for Computing Sciences in Colleges

Full text available:  [pdf\(417.27 KB\)](#) Additional Information: [full citation](#), [abstract](#), [references](#), [index terms](#)

This paper discusses the advantages and disadvantages of using SIVIL (SIMple VISual Language), a new visual programming language in development at Canisius College, to teach novice programmers to think more deeply about programming. In consideration of how SIVIL meets its goal of making programming easier for beginners, the paper will look at Bloom's Taxonomy, specifically at Bloom's levels of learning and how a visual language might aid or speed up the learning curve for students endeavoring ...

### 35 Debugging agent interactions: a case study



David Flater

March 2001 **Proceedings of the 2001 ACM symposium on Applied computing**

**Publisher:** ACM Press

Full text available:  [pdf\(327.60 KB\)](#) Additional Information: [full citation](#), [references](#), [citations](#), [index terms](#)

**Keywords:** agents, coordination, negotiation, scheduling

### 36 Track 4: reconfigurable computing (part 2): Owl: next generation system monitoring



Martin Schulz, Brian S. White, Sally A. McKee, Hsien-Hsin S. Lee, Jürgen Jeitner

May 2005 **Proceedings of the 2nd conference on Computing frontiers**

**Publisher:** ACM Press

Full text available:  [pdf\(430.90 KB\)](#) Additional Information: [full citation](#), [abstract](#), [references](#), [index terms](#)

As microarchitectural and system complexity grows, comprehending system behavior becomes increasingly difficult, and often requires obtaining and sifting through voluminous event traces or coordinating results from multiple, non-localized sources. Owl is a proposed framework that overcomes limitations faced by traditional performance counters and monitoring facilities in dealing with such complexity by pervasively deploying programmable monitoring elements throughout a system. The design exploits ...

**Keywords:** autonomous performance monitoring, performance analysis, reconfiguration

### 37 VAX DEBUG: an interactive, symbolic, multilingual debugger



Bert Beander

March 1983 **ACM SIGSOFT Software Engineering Notes , ACM SIGPLAN Notices , Proceedings of the symposium on High-level debugging SIGSOFT '83,** Volume 8 ,  
18 Issue 4 , 8

**Publisher:** ACM Press

Full text available:  [pdf\(655.76 KB\)](#) Additional Information: [full citation](#), [abstract](#), [references](#)

Digital Equipment Corporation's VAX-11 Debugger, usually called VAX DEBUG or simply DEBUG, is an interactive, symbolic, and multilingual debugger which runs on the VAX-11 series of computers under the VMS operating system. The following gives an overview of VAX DEBUG and examines how it solves some of the problems inherent in the design of any such debugger. Particular attention is paid to how its command language is designed, how it distinguishes between addresses and values in command input, h ...

### 38 Interactive debug requirements

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Rich Seidner, Nick Tindall

March 1983 **ACM SIGSOFT Software Engineering Notes , ACM SIGPLAN Notices ,  
Proceedings of the symposium on High-level debugging SIGSOFT '83**, Volume 8 ,  
18 Issue 4 , 8

**Publisher:** ACM PressFull text available: [pdf\(1.25 MB\)](#)Additional Information: [full citation](#)**39** Software and systems: Obfuscation of design intent in object-oriented applications

Mikhail Sosonkin, Gleb Naumovich, Nasir Memon

October 2003 **Proceedings of the 2003 ACM workshop on Digital rights management****Publisher:** ACM PressFull text available: [pdf\(368.61 KB\)](#)Additional Information: [full citation](#), [abstract](#), [references](#), [index terms](#)

Protection of digital data from unauthorized access is of paramount importance. In the past several years, much research has concentrated on protecting data from the standpoint of confidentiality, integrity and availability. Software is a form of data with unique properties and its protection poses unique challenges. First, software can be reverse engineered, which may result in stolen intellectual property. Second, software can be altered with the intent of performing operations this software m ...

**Keywords:** code generation, refactoring, software obfuscation**40** Reliability and security: Hardware assisted control flow obfuscation for embedded processors

Xiaotong Zhuang, Tao Zhang, Hsien-Hsin S. Lee, Santosh Pande

September 2004 **Proceedings of the 2004 international conference on Compilers, architecture, and synthesis for embedded systems****Publisher:** ACM PressFull text available: [pdf\(275.14 KB\)](#)Additional Information: [full citation](#), [abstract](#), [references](#), [citations](#), [index terms](#)

With more applications being deployed on embedded platforms, software protection becomes increasingly important. This problem is crucial on embedded systems like financial transaction terminals, pay-TV access-control decoders, where adversaries may easily gain full physical accesses to the systems and critical algorithms must be protected from being cracked. However, as this paper points out that protecting software with either encryption or obfuscation cannot completely preclude the control flo ...

**Keywords:** control flow graph, obfuscation

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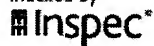
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